

Interpretation of Bioassay Measurements

Manuscript Completed: June 1987
Date Published: July 1987

Prepared by

Edward T. Lessard, Brookhaven National Laboratory, Upton, New York
Xia Yihua, Institute of Atomic Energy, Beijing, People's Republic of China
Kenneth W. Skrable, University of Lowell, Lowell, Massachusetts
George E. Chabot, University of Lowell, Lowell, Massachusetts
Clayton S. French, University of Lowell, Lowell, Massachusetts
Thomas R. Labone, University of Lowell, Lowell, Massachusetts
John R. Johnson, Chalk River Nuclear Laboratory, Ontario, Canada
Darrell R. Fisher, Battelle Pacific Northwest Laboratory, Richland, Washington
Richard Belanger, Science Applications International Corporation, San Diego, California
Joyce Landmann Lipsztein, Commissao Nacional de Energia Nuclear, Sao Paulo, Brazil

NRC Project Managers - B.G. Brooks and A. Brodsky

Prepared for

Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN A-3289

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, or any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use, or the results of such use, of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

The views expressed in this report are not necessarily those of the U.S. Nuclear Regulatory Commission.

Available from
Superintendent of Documents
U.S. Government Printing Office
P.O. Box 37082
Washington, DC 20013-7982
and
National Technical Information Service
Springfield, Virginia 22161

ABSTRACT

This is a comprehensive manual describing how to compute intakes from both in-vivo and in-vitro bioassay measurements. To date, interpretations of intake have been inconsistent, particularly in the early phases after an accidental intake. This manual is aimed at completely describing a consistent approach and instructing others on how to compute intakes and committed organ dose equivalents. Tables for the interpretation of bioassay results are compiled for several hundred radionuclides. Measurements which employ a whole-body counter, a thyroid counter, a lung counter, or measurements on excreta can be converted into estimates of intake based on the tables presented in the appendices. The values in the tables were determined by using lung, gastrointestinal tract and systemic retention models published by the International Commission on Radiological Protection (ICRP79). In a few cases, pseudo-retention functions, organ retention functions, and excretion functions were used to generate the tabulated values. The biological and radiological input parameters are included in an appendix, and a description of the mathematical approach that was used to derive the tabulated data is included in the methods section. Calculations for various particle sizes are addressed along with methods to interpret multiple or continuous exposures. Examples of use are based on actual bioassay measurements following accidental intakes, including tritium, Mn-54, Co-60, Sr-90, Nb-95, radioiodines, Cs-137, Ce-141, Ce-144, U-233, U-Nat, and Am-241.

CONTENTS

	<u>Page</u>
ABSTRACT.....	iii
LIST OF FIGURES.....	viii
LIST OF TABLES.....	ix
PREFACE.....	xi
ACKNOWLEDGMENT.....	xiii
1. INTRODUCTION	1
1.1 Problems Associated with Internal Dose Assessment.....	1
1.2 Criteria for Selecting This Approach, Literature Reviewed, Validation and Verification Methods.....	2
1.3 Premise of the Manual.....	3
2. DESCRIPTION OF CALCULATIONAL METHOD.....	4
2.1 Introduction.....	4
2.2 Terminology Needed for Interpretation of Bioassay Measurements.....	6
2.3 Limitations Associated with Use of Metabolic Models.....	9
2.4 Intake Retention Functions and Their Applications.....	9
2.5 Catenary Pathways from Intake to Excretion.....	10
2.5.1 Radioelement Intake Retention Function $i_n(t)$ for the n^{th} Catenary Compartment.....	15
2.5.2 Inhalation Intake Retention Functions for Lungs.....	16
2.5.2.1 Inhalation Intake Retention Functions for GI Tract and Accumulated Feces.....	16
2.5.2.2 Inhalation Intake Retention Functions for the Systemic Whole Body and Urinary Excretion for Stable Cobalt.....	17
3. RETENTION AND EXCRETION FRACTION TABLES.....	21
3.1 Description of Tables.....	21
3.2 Best Estimate of Intake from Several Bioassay Measurements.....	22
4. USE OF RETENTION FRACTIONS TO CALCULATE INTERNAL DOSE.....	23
4.1 An Example of Use for Inhalation of Class D I-131.....	23
5. DESIGN AND CONDUCT OF A BIOASSAY PROGRAM.....	25
5.1 Derived Investigation Levels.....	25
5.2 Frequency of Monitoring.....	26
5.3 Table of Derived Investigation Levels.....	27
6. GENERAL EVALUATION.....	33
6.1 Validation of Tabulated Results.....	33

6.1.1	General Description of the REMedy Model.....	33
6.1.2	General Description of DOSEDAY and DOSEYR.....	34
6.1.3	Input Values for Validation Tests.....	34
6.1.4	Validation Results.....	35
6.1.5	Conclusions Drawn from Validation Study.....	36
6.2	Applications and Limitations of IRF Values.....	48
6.2.1	Pitfalls Associated w/Interpreting Bioassay Measurements...	48
6.3	Recommendations for Further Study.....	50
7.	SUMMARY.....	51
8.	BIBLIOGRAPHY.....	52
APPENDIX A - EXAMPLE OF USE AND VERIFICATION BASED ON EXPERIENCES.....		A-1
1.	INTRODUCTION.....	A-1
2.	INHALATION OF CLASS D URANIUM.....	A-2
3.	INHALATION OF CLASS D Cs-137 AND CLASS W Co-60.....	A-5
4.	RADIOIODINE INGESTION AND INHALATION.....	A-6
5.	INHALATION OF THORIUM AND URANIUM.....	A-11
6.	EXPOSURE TO TRITIUM.. ..	A-14
7.	VERIFICATION OF INHALATION AND INGESTION MODELS FOR Mn-54, Co-60 Sr-90, Nb-95, Cs-137, Ce-141, Ce-144, U-233, and Am-241.....	A-15
8.	BIBLIOGRAPHY	A-30
APPENDIX B - TABULATED DATA.....		B-1
1.	INTRODUCTION.....	B-1
1.1	Class D Tables Listed by Atomic Number.....	B-2
1.2	Class W Tables Listed by Atomic Number.....	B-4
1.3	Class Y Tables Listed by Atomic Number.....	B-6
1.4	Ingestion Tables Listed by Atomic Number.....	B-7
1.5	Biological and Radiological Parameters Listed by Atomic Number...	B-9
2.	TABLES OF RETENTION AND EXCRETION FRACTIONS FOR SINGLE INHALATION OF CLASS D AEROSOLS OF 1 MICROMETER AMAD.....	B-12
3.	TABLES OF RETENTION AND EXCRETION FRACTIONS FOR SINGLE INHALATION OF CLASS W AEROSOLS OF 1 MICROMETER AMAD.....	B-164
4.	TABLES OF RETENTION AND EXCRETION FRACTIONS FOR SINGLE INHALATION OF CLASS Y AEROSOLS OF 1 MICROMETER AMAD.....	B-359
5.	TABLES OF RETENTION AND EXCRETION FRACTIONS FOR SINGLE INGESTION.....	B-467
6.	TABLES OF RETENTION AND EXCRETION FRACTIONS FOR SINGLE INTAKE OF C-14 DIOXIDE, C-14 MONOXIDE, AND H-3 WATER OR VAPOUR.....	B-708
7.	BIOLOGICAL AND RADIOLOGICAL PARAMETERS USED IN THIS STUDY.....	B-712

8. RETENTION FRACTION FOR SIZE DISTRIBUTIONS OTHER THAN 1 MICROMETER AMAD.....	B-800
9. RETENTION FRACTION FOR MULTIPLE AND CONTINUOUS INTAKES OF SELECTED NUCLIDES.....	B-803
10. BIBLIOGRAPHY.....	B-808
11. ALPHABETICAL INDEX TO APPENDIX B.....	B-809

LIST OF FIGURES

	<u>Page</u>
2.1 Catenary pathways from intake to excretion.....	12
2.2 Inhalation intake retention functions for lungs for 1 micro- meter AMAD aerosols of stable Class D, W, or Y compounds.....	18
2.3 Inhalation intake retention functions for GI tract and accumulated feces for 1 micrometer AMAD aerosols of stable Class D, W, or Y compounds for which f_l and f_f equal zero.....	19
2.4 Systemic retention and urinary excretion post single inhalation intake of 1 micrometer AMAD aerosols of stable Class W, cobalt for which $f_l = 0.05$ and $f_u = 0.8$	20

LIST OF TABLES

	<u>Page</u>
4.1.1 Example of Intake Estimate for Iodine-131 Exposure Using Two Different Measuring Devices and Thyroid IRFs.....	24
5.1.1 Derived Investigation Levels for Urine Samples and Time Post Intake of Class W, 1 Micrometer AMAD Aerosols of 70.8 Day Co-58.....	26
5.3.1 Derived Investigation Levels for an Acute Intake.....	28
6.1.1 Validation of Inhalation Results for Excreta Measurements.....	37
6.1.2 Validation of Inhalation Results for In Vivo Measurements.....	43
6.1.3 Validation of Ingestion Results.....	46
6.1.4 Validation of Thyroid Retention Results.....	47

PREFACE

The purpose of this report is to provide a practical and consistent method for estimating intakes from bioassay measurements, and to provide guidance in order to establish an effective internal radiation protection program. Our procedure for estimating intakes provides a way to rapidly assess the significance of an exposure. Users of this document will be able to demonstrate compliance with the provisions of 10CFR Part 20, and be able to assure adequate interpretation of bioassay measurements. Additionally this report may be useful in order to (1) establish derived investigation levels in the body or in excreta of exposed persons, (2) determine the frequency of monitoring individuals, and (3) determine the appropriate method of monitoring. Users of this document will be able to adjust their estimate of intake for particle sizes between 0.2 and 10 micrometers, and be able to interpret measurements associated with single, multiple or continuous intakes. Use of this report may also lead to further refinement of models which are used to interpret bioassay measurements.

ACKNOWLEDGMENT

The authors would like to thank Mr. Robert E. Alexander, Office of Nuclear Regulatory Research, United States Nuclear Regulatory Commission, for having the vision and initiative to appreciate the need for this work, to obtain the funds for it, and to recommend a group to work on the project.

We wish to express our sincere appreciation for the scientific review and sound advice from Dr. Allen Brodsky, Program Manager, Radiation Risk Management, Nuclear Regulatory Commission, and from Dr. John Baum, Associate Head for Research, Safety and Environmental Protection Division, Brookhaven National Laboratory. Additionally, we wish to thank Barbara Brooks, Program Manager, Office of Nuclear Regulatory Research, Nuclear Regulatory Commission, for helping to bring this program to completion.

We wish to acknowledge the contributions of the following persons and thank them for a job well done. They are: E.P. Hope, C.L. Clary, and B.E. Kirstein, Science Applications International Corporation; we thank them for modifying and applying the REMedy and DOSEDAY/DOSEYR programs for use in the validation effort. We also thank Marie Cooney, Brookhaven National Laboratory for typing the manuscript, and Cheryl Christie for assisting in this work.